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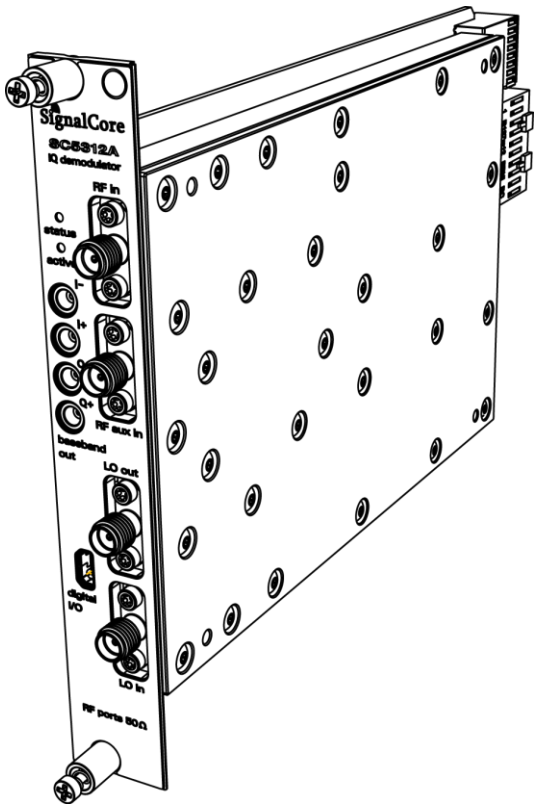

SC5312A
400 MHz to 6 GHz IQ Demodulator
PXI Express Interface

Operating and Programming Manual

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IMPORTANT INFORMATION

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組成名稱 **Model Name**	鉛 **Lead (Pb)**	汞 **Mercury (Hg)**	镉 **Cadmium (Cd)**	六价铬 **Hexavalent Chromium (Cr(VI))**	多溴联苯 **Polybrominated biphenyls (PBB)**	多溴二苯醚 **Polybrominated diphenyl ethers (PBDE)**
SC5312A	✓	✓	✓	✓	✓	✓

A ✓ indicates that the hazardous substance contained in all of the homogeneous materials for this product is below the limit requirement in SJ/T11363-2006. An **X** indicates that the particular hazardous substance contained in at least one of the homogeneous materials used for this product is above the limit requirement in SJ/T11363-2006.

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(product safety), and comply with the relevant standards. Standards for Measurement, Control and Laboratory Equipment include EN 61326 and EN 55011 for EMC, and EN 61010-1 for product safety.

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GETTING STARTED

Unpacking

All SignalCore products ship in antistatic packaging (bags) to prevent damage from electrostatic discharge (ESD). Under certain conditions, an ESD event can instantly and permanently damage several of the components found in SignalCore products. Therefore, to avoid damage when handling any SignalCore hardware, you must take the following precautions:

- Ground yourself using a grounding strap or by touching a grounded metal object.
- Touch the antistatic bag to a grounded metal object before removing the hardware from its packaging.
- *Never* touch exposed signal pins. Due to the inherent performance degradation caused by ESD protection circuits in the RF path, the device has minimal ESD protection against direct injection of ESD into the RF signal pins.
- When not in use, store all SignalCore products in their original antistatic bags.

Remove the product from its packaging and inspect it for loose components or any signs of damage. Notify SignalCore immediately if the product appears damaged in any way.

Verifying the Contents of your Shipment

Verify that your SC5312A kit contains the following items:

Quantity	Item
1	SC5312A IQ Demodulator
1	USB Flash Drive Installation Software (may be combined with other products onto a single drive)
1	Getting Started Guide

Setting Up and Configuring the SC5312A

The SC5312A is a designed for use in a PXIe or PXIe hybrid chassis. Chassis manufacturers must provide at least the minimum required per-slot power dissipation cooling capability to be compliant with the PXIe specifications. The SC5312A is designed to be sufficiently cooled in either all-PXIe chassis or PXIe hybrid chassis (PXI Express chassis with traditional PXI slots). However, certain environmental factors may degrade performance. Inadequate cooling can cause the temperature inside the RF housing to rise above the maximum for this product, leading to improper performance and potentially reducing product lifespan or causing complete product failure. Maintain adequate air space around the chassis at all times, and keep the chassis fan filters clean and unobstructed.

Refer to your chassis manufacturer's user manual for proper setup and maintenance of your PXIe or PXIe hybrid chassis. The SC5505A on-board temperature sensor should indicate a rise of no more than 20 °C above ambient temperature under normal operating conditions.

The SC5312A is a PXIe-based IQ demodulator with all I/O connections and indicators located on the front face of the module as shown in **Error! Reference source not found.**. Each location is discussed in further detail below.

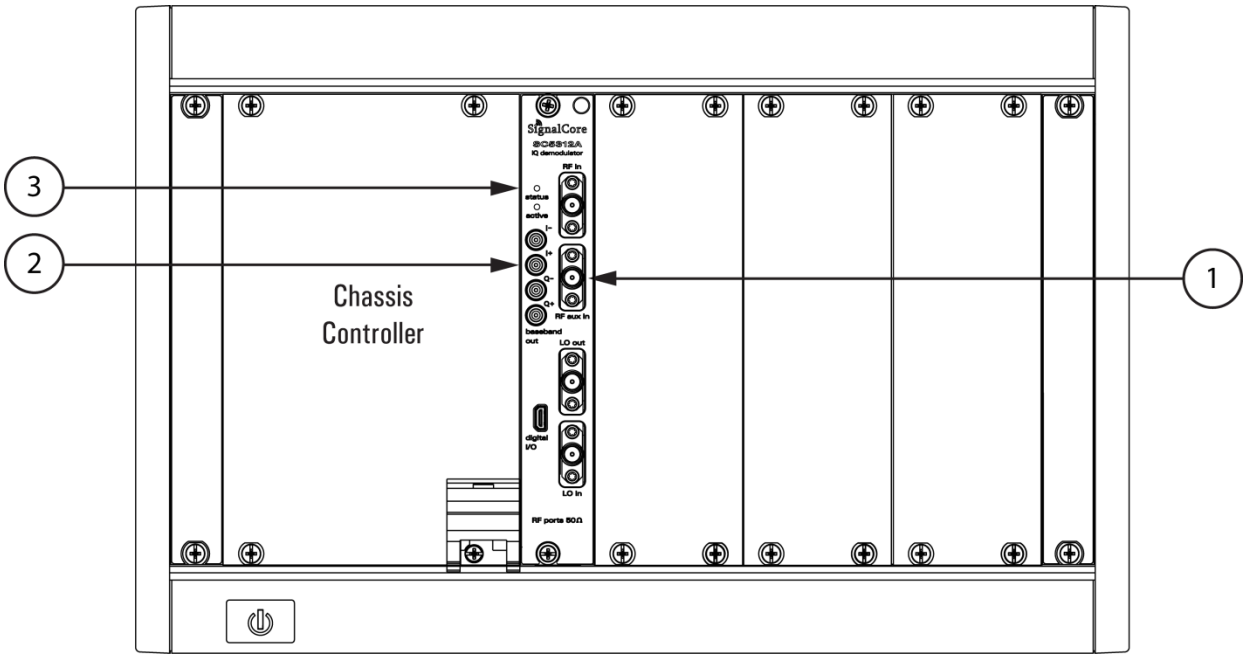

Figure 1. PXIe chassis view of the SC5312A. Module is shown installed in slot 2.

All RF signal connections (ports) on the SC5312A are SMA-type. Exercise caution when fastening cables to the signal connections. Over-tightening any connection can cause permanent damage to the device.

The condition of your system's signal connections can significantly affect measurement accuracy and repeatability. Improperly mated connections or dirty, damaged or worn connectors can degrade measurement performance. Clean out any loose, dry debris from connectors with clean, low-pressure air (available in spray cans from office supply stores).

If deeper cleaning is necessary, use lint-free swabs and isopropyl alcohol to gently clean inside the connector barrel and the external threads. Do not mate connectors until the alcohol has completely evaporated. Excess liquid alcohol trapped inside the connector may take several days to fully evaporate and may degrade measurement performance until fully evaporated.

Tighten all SMA connections to 5 in-lb max (56 N-cm max)

1 RF Signal Connections

LO OUT This port outputs the tunable LO signal allowing phase-coherent daisy-chaining of multiple IQ demodulator modules. The connector is SMA female. The nominal output impedance is 50 Ω.

RF IN This port accepts an RF signal ranging from 400 MHz to 6 GHz. The connector is SMA female. The nominal input impedance is 50 Ω. Maximum input power is +23 dBm with ATTEN #1 set to at least 10 dB attenuation.

RF AUX IN This port accepts an RF signal ranging from 400 MHz to 6 GHz. This port can be used as an alternate path for system-level calibration. The connector is SMA female. The nominal input impedance is 50 Ω.

LO IN This port accepts a tunable LO signal from an external source to drive the demodulator. The connector is SMA female. This port is AC-coupled with a nominal input impedance of 50 Ω. Maximum input power is +10 dBm.

2 Baseband Connections

The SC5312A has four baseband output ports, comprised of differential in-phase (I+ and I-) and differential quadrature (Q+ and Q-) outputs. Nominal differential output impedance is 100 Ω. The demodulator can also be configured for single-ended or differential IF output. When configured for single-ended operation, it is recommended to terminate the other half of the differential pair using a 50 Ω terminator. All baseband connectors are MCX female.

3 Indicator LED

The SC5312A provides visual indication of important modes. There is one LED indicator on the unit. Its behavior under different operating conditions is shown in Table 1.

Table 1. LED indicator states.

LED	Color	Definition
STATUS	Green	“Power good” and device is ready.
STATUS	Off	Power fault. Contact SignalCore.
ACTIVE	Green/Off	Device is open (green) /closed (off). This indicator is also user programmable (see register map).

SC5312A Theory of Operation

Overview

The SC5312A is a single-stage, direct coversion Inphase-Quadrature (IQ) demodulating mixer, or simply an IQ demodulator. The SC5312A can operate as a single-stage downconverter or as an IQ demodulator. The SC5312A demodulator operates in the 400 MHz to 6 GHz RF range with a typical 3 dB IF bandwidth of 160 MHz in single-stage converter mode, or 320 MHz in IQ mode. The RF input stage has adjustable gain to allow the user to adjust the incoming RF signal prior to the demodulation process for the purpose of optimizing RF dynamic range. The IF stage has adjustable gain to ensure that linearity and noise of the IF output are optimized. The SC5312A has the necessary RF amplifiers, attenuators, IF amplifiers, and IF control via DACs to allow the user to optimally operate the device over the entire frequency range as well as for both small and large RF input levels. Figure 2 shows a simplified block diagram of the SC5312A, showing only the signal conditioning components critical for the following discussion. The following sections below provide more in-depth discussion on how to optimize the converter for linearity and signal-noise dynamic range. Power supply generation and regulation, and digital control functions are not covered. Should the user require more information than what is provided in this manual, please contact SignalCore.

RF Input Section

In the design of the RF input section, care was taken to ensure that the dynamic range of the IQ demodulator is preserved as seen at the input port of the device. This requires that the demodulator is not driven too hard (high signal amplitude) nor too soft (low signal amplitude). When the device is driven hard, nonlinear effects dominate the system. When driven too softly, signal-to-noise dynamic range suffers. A general rule is to apply more attenuation earlier in the RF signal path to improve linearity, and more gain to improve signal-to-noise performance. As an example, for a given input signal level and while maintaining a relatively constant output IF level, the user would switch in RF AMP#1 and apply attenuation on ATTEN#3 to improve signal-to-noise dynamic range. The factory default state sets all the RF amplifiers off, all attenuators set to 0 dB attenuation, and the IF gain set to 8 dB (DAC code of 32). In this default state, the device is optimized for a -10 dBm RF signal in the 1.0 GHz to 2.4 GHz range. The IF output is typically 0.5 V – 1.0 V peak-to-peak differential at these settings.

The RF amplifiers are used to improve the gain of the device if the input signal is too low or when the losses at higher frequencies are large. RF AMP#1 is usually selected when the RF signals are lower than -25 dBm at the input port. With RF AMP#1 enabled, the device sensitivity is improved and the detection of low level signals is better resolved. RF AMP#2 should be selected and switched into the signal path at RF frequencies greater than 5 GHz, where the signal power loss through the front end prior to the demodulator can be as high as 15 dB due to filter and switch insertion losses. At these high RF frequencies, if the IF gain is at its maximum of 15.75 dB (DAC code = 63) and the IF output level falls below -10 dBm or outside the digitizers optimal levels, RF AMP#2 should be enabled.

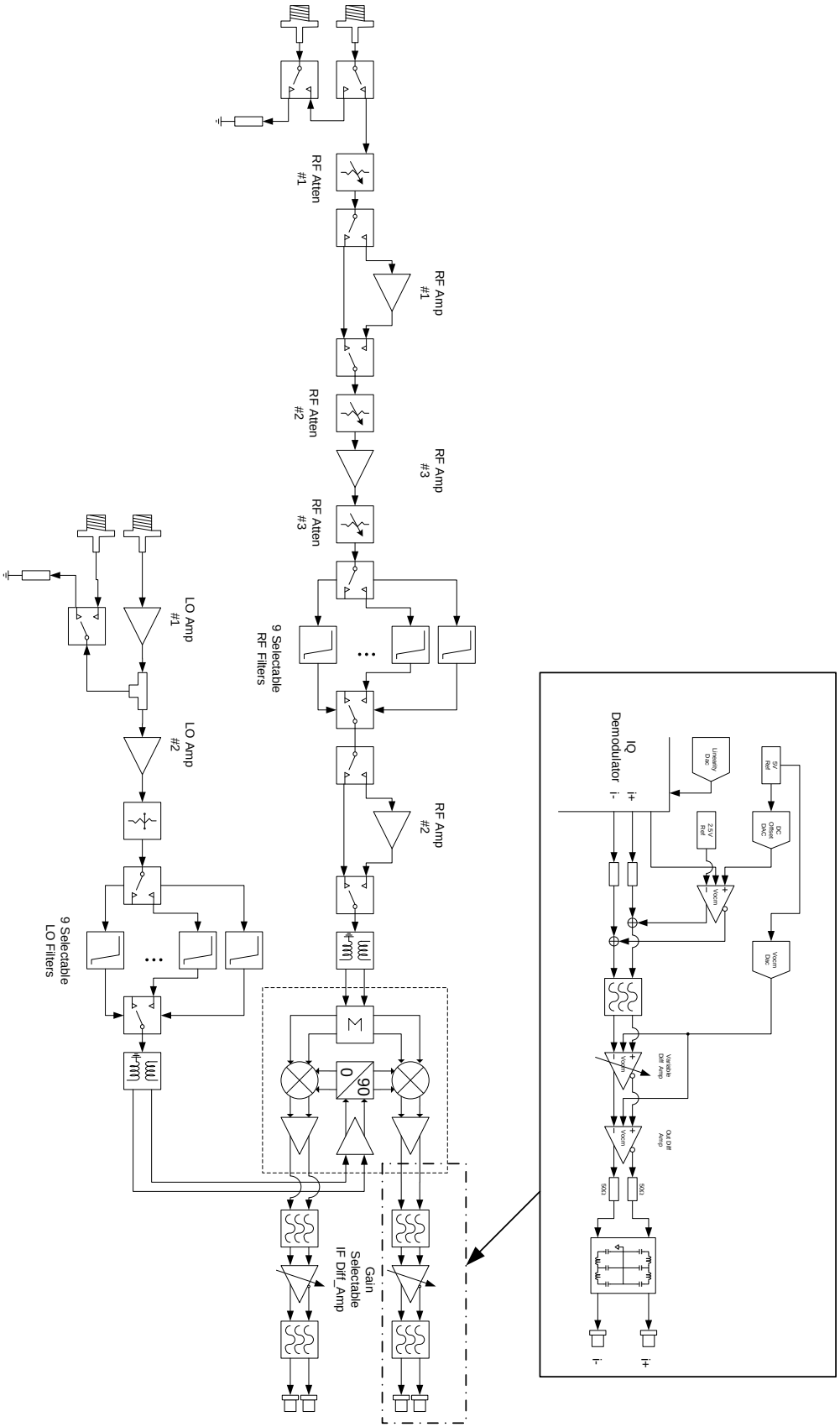

Figure 2. Simplified block diagram of the SC5312A.

The RF attenuators provide attenuation when required. RF ATTEN#1 attenuation should be stepped up as the signal power at the RF port increases above -10 dBm. Nonlinear components of the signal such as IMD3 and second order harmonics will increase in magnitude as the input signal increases; therefore the user should exercise good judgment to determine when to use RF ATTEN#1. Do not over-attenuate. Doing so will negatively impact the signal-to-noise ratio.

RF ATTEN#2 is used when if the input signal needs further suppression to improve linearity. It should also be used if RF AMP#1 is enabled to improve sensitivity, but as a result the level at the input of RF AMP#3 (always in the path) may be too high. Step up the attenuation of RF ATTEN#2 to ensure the system (resulting from RF AMP#3) is not driven too hard. Finally RF ATTEN#3 is used to control the level to the IQ demodulator when RF AMP#2 is enabled (switched into the signal path).

There is also an auxiliary RF input to the device. This input is almost identical to the main RF input with the exception of having an extra switch path. The intended use of this port is to allow the user a calibration path without having to detach the device under test (DUT) already cabled to the main RF input port. The user must perform in-situ equalization to remove IQ errors such as phase imbalance and quadrature gain offsets that are inherent to the device. Providing this auxiliary path makes the task of characterizing the system with and without a DUT present much easier.

There are nine low pass filters in the RF filter bank. These filters are automatically selected when the user enters the operating frequency. These filters can also be selected manually should the user choose to do so. As with all filters there is generally an amplitude roll-off as the frequency nears its 3 dB cutoff point so it is important to understand that frequencies near to the cutoff point may experience a slightly faster roll-off of its IF bandwidth. A typical 1 dB IF bandwidth (IQ) is about 160 MHz. The user may want to choose a higher frequency filter if this becomes a problem. See the programming section in this manual for more details. The filters in both the RF and LO filter banks are identical and are listed below.

Filter Number	1 dB Cutoff Frequency
0	400 MHz
1	500 MHz
2	650 MHz
3	1000 MHz
4	1400 MHz
5	2000 MHz
6	2825 MHz
7	3800 MHz
8	6000 MHz

LO Input Section

The SC5312A requires an external RF signal as its “Local Oscillator” (LO) for the frequency conversion process. The external RF signal must be connected to the “LO in” port. The typical required input level is -3 dBm to 3 dBm. These levels are required to sufficiently drive the IQ demodulator for good linearity performance and conversion loss. The LO signal is conditioned through a bank of low-pass filters to

reduce the signal harmonics. Reducing the harmonics produces a “purer” signal tone, improving the duty cycle of the LO as it drives the mixers of the demodulator. Additionally, the LO signal can be passed out of the device via the “LO out” port. This output can be used as the input LO source for another demodulator, for example. Driving multiple demodulators (or modulators when working with SignalCore’s SC5413A) with the same derived LO signal optimizes phase coherency between them. When this port is not in use, it is highly recommended to terminate it into a 50 Ω load.

IF Output Section

The IF outputs are differentially driven. Each of the in-phase and quadrature components of the demodulator is conditioned prior to leaving the IF ports. The user can programmatically adjust the parameters of the differential signal such as the common output voltage, DC offset between the (-) and (+) terminals, and its amplitude. The differential output impedance of each component is 100 Ω and DC coupled. However, all ports can be operated as AC coupled single-ended 50 Ω ports. All unused ports should be terminated into AC couple 50 Ω loads.

There are voltage DACs within the device to control the signal parameters of each of the IQ components. For each component, the Vcom (common voltage) DAC controls the common output voltage of the differential outputs. The Vcom DAC values range from 0 to 16383 (14 bits) and change the voltage between 1 V to 3.5 V. For a wider output voltage swing range, this voltage should be set to around 2.4 V to 2.5 V. Having a wider swing range improves the output compression point of the device. This is not a hard requirement and the user will need to adjust the voltage levels to suit their specific requirements. As an example, setting to some other voltage may be required to optimize the dynamic range of the receiving digitizer and as a result better optimize the entire system.

DC offsets may limit the dynamic range of the receiving digitizer, and where it is critical the user can “tune out” to minimize these offsets using the DC Offset DAC. This 14 bit DAC can correct offsets up to +/-0.050 V with less than 0.010 mV resolution.

The IF amplifiers have adjustable gain ranges from 0 to 15.75 dB, with a tuning resolution of 0.25 dB. The gain is controlled by programming a 6-bit DAC whose codes range from 0 to 63. Writing 63 to the DAC provides the highest gain. Increasing the IF gain instead of the RF gain to achieve a required IF level will improve the linearity of the system, but with the chance of a slight increase in output noise. For a common output voltage of 2.4 V, the output compression/saturation point of the amplifier is around 10 dBm. It is recommended to operate the output at least 6 dBm below this value to avoid running into saturation from signals with high crest factors. When deciding the operating point of the digitizer, it is recommended that the user not operate the output voltage too close to the saturation point of the digitizer input.

The linearity DAC controls the current flow throw the demodulator core and thus affects the linearity of the device. Generally, increasing the voltage results in higher the current consumption, and as a result the linearity improves. However slight adjustments to the voltage may improve the linearity further; this is dependent on the frequency and input power.

SC5312A Programming Interface

Device Drivers

The SC5312A is programmed by writing to its set of configuration registers, and its data is read back through its set of query registers. The user may program directly at register level or through the API library functions provided. These API library functions are wrapper functions of the registers that simplify the task of configuring the register bytes. The register specifics are covered in the next section. Writing to and reading from the device at the register level through the API involves calls to the **SC5312A_RegWrite** and **SC5312A_RegRead** functions respectively.

The SC5505A is programmed by writing to its set of configuration registers, and its status read back through its set of query registers. The user may choose to program directly at register level or through the API library functions provided. These API library functions are wrapper functions of the registers that simplify the task of configuring of the register bytes. The register specifics are covered in the next section. Writing to and reading from the device at the register level through the API involves calls to the **sc5312a_RegWrite** and **sc5312a_RegRead** functions respectively.

For Microsoft Windows™ operating systems, The SC5312A API is provided as a dynamic linked library, *sc5312a.dll*. This API uses **NI-VISA**™ to communicate with the device. Inclusion of the NI-VISA driver is required for code development in programming languages such C, C++, or LabVIEW™. For LabVIEW™ support, an additional LabVIEW API, sc5312a.llb, is also provided. The functions in the LabVIEW API are primarily LabVIEW VI wrappers to the standard API functions. **NI-VISA**™ is available from National Instruments Corporation (www.ni.com).

For other operating systems or VISA implementations such as Agilent VISA, users will need to access the device through their own proprietary PXIe driver. The VISA-based driver code is available to our customers by request. This code can be compiled with Agilent VISA with minimal or no code change. Should the user require assistance in writing an appropriate API other than that provided, please contact SignalCore for additional example code and hardware details.

Using the Application Programming Interface (API)

The SC5312A API library functions make it easy for the user to communicate with the device. Using the API removes the need to understand register-level details - their configuration, address, data format, etc., and the additional layer between the PXIe bridge and the onboard microcontroller that must be configured prior to writing the device registers. Using the API, commands to control the device are greatly simplified. For example, to obtain the device temperature, the user simply calls the function **sc5312A_GetDeviceTemperature**, or calls **sc5312A_SetFrequency** to tune the frequency. The software API is covered in detail in the “Software API Library Functions” section.

SETTING THE SC5312A: WRITING TO CONFIGURATION REGISTERS

Configuration Registers

The users may write the configuration registers (write only) directly by calling the **SC5312A_RegWrite** function. The syntax for this function is **SC5312A_RegWrite(deviceHandle, registerCommand, instructWord)**. The **instructWord** takes a 64 bit-word. However, it will only send the required number of bytes to the device. Table 2 summarizes the register addresses (commands) and the effective bytes of command data.

Table 2. Configuration registers.

Register (Address)	Reg Code	Serial Range	MSB Bit 7	MSB Bit 6	MSB Bit 5	MSB Bit 4	MSB Bit 3	MSB Bit 2	MSB Bit 1	MSB Bit 0
INITIALIZE	0x01	[7:0]								Mode
SET_SYSTEM_ACTIVE	0x02	[7:0]								Enable SYS LED
RF_FREQUENCY	0x10	[7:0]	MHz Frequency Word [7:0]							
		[15:8]	MHz Frequency Word [15:8]							
		[23:16]	MHz Frequency Word [23:16]							
		[31:24]	MHz Frequency Word [31:24]							
		[39:32]	MHz Frequency Word [39:32]							
RF_AMPLIFIER	0x12	[7:0]							Amplifier	Mode
RF_ATTENUATION	0x13	[7:0]			Attenuation					
		[15:8]							Attenuator #	
RF_PATH	0x14	[7:0]								Path
RF_FILTER_SELECT	0x15	[7:0]					Filter [3:0]			
LO_FILTER_SELECT	0x16	[7:0]					Filter [3:0]			
LO_OUT_ENABLE	0x17	[7:0]								Enable SYS LED
IF_GAIN_DAC	0x18	[7:0]			DAC value [5:0]					
		[15:8]								Channel
VCOM_OUT_DAC	0x19	[7:0]	DAC value [7:0]							
		[15:8]			DAC value [13:8]					
		[23:16]								Channel
DC_OFFSET_DAC	0x1A	[7:0]	DAC value [7:0]							
		[15:8]			DAC value [13:8]					
		[23:16]								Channel
LINEARITY_DAC	0x1B	[7:0]	DAC value [7:0]							
		[15:8]			DAC value [13:8]					
STORE_STARTUP_STATE	0x1D	[7:0]								
USER_EEPROM_WRITE	0x1F	[7:0]	Address [7:0]							
		[15:8]	Address [15:8]							
		[23:16]	Byte[7:0]							

To write to the device through USB transfers such as bulk transfer, it is important to send the data with the register byte first, followed by the most significant bit (MSB) of the data bytes. For example, to set the attenuation value of ATTEN#2, the byte stream would be [0x13][15:8][7:0].

Initializing the Device

INITIALIZE (0x01) - Writing 0x00 to this register will reset the device to the default power-on state. Writing 0x01 will reset the device but leave it in the current state. The user has the ability to define the default startup state by writing to the **START UP STATE (0x23)** register, described later in this section.

Setting the System Active LED

SET_SYSTEM_ACTIVE (0x02) - This register simply turns on the front panel "active" LED with a write of 0x01, or turns off the LED with a write of 0x00. This register is generally written when the device driver opens or closes the device.

Setting the RF Frequency

RF_FREQUENCY (0x10) - This register provides the device frequency information to set up the filters appropriately. Data is sent as a 40 bit word with the LSB in Hz.

Setting RF Input RF Amplifiers

RF_AMPLIFIER (0x12) - This register enables or disables the RF amplifiers. Setting bit 0 low (0) disables RF amplifier. Setting bit 0 high (1) enables RF amplifier. Bit 1 selects the amplifier; 0 for RF AMP#1, 1 for RF AMP#2.

Setting the RF Attenuation

RF_ATTENUATION (0x13) – Each of the attenuators is a 5 bit digital step attenuator with 1 dB per LSB. Data is sent in 2 bytes; byte1 and bits [1:0] specifies the attenuator to program, and byte0 and bit [4:0] specifies the attenuation value.

Setting the RF Path

RF_PATH (0x14) – Setting bit 0 low selects the main RF input path, while high will select the RF auxiliary path.

Selecting the RF Filter

RF_FILTER_SELECT (0x15) – There are 9 RF filters to select from to improve RF input second harmonic suppression. Bits [3:0] are used.

Selecting the LO Filter

LO_FILTER_SELECT (0x16) – There are 9 RF filters to select from to improve LO input second harmonic suppression. Bits [3:0] are used.

Enabling LO Output

LO_OUT_ENABLE (0x17) – Setting bit 0 high enables the LO signal to be ported out the LO output connector. Note there is always a leakage out of this port and the levels could be as high as -30 dBm. It is recommended to terminate this port into a 50 Ω load if it is not used.

Setting the IF Gain

IF_GAIN_DAC (0x18) – Each of the channels has an adjustable IF amplifier with a step resolution of 0.25 dB per LSB. Writing the associated 6-bit DAC provides a gain range of 0 dB to 15.75 dB. Byte 1 selects the channel, while byte 0 determines the DAC value. A maximum DAC value of 63 will provide maximum gain.

Setting the Common Output Voltage

VCOM_OUT_DAC (0x19) – The common output voltage of each channel of differential amplifiers can be adjusted by writing to this DAC. The output voltage is linear in the region of 1.0 V to 3.5 V and follows the equation:

$$DAC\ Value = 16383\left({V_{com}}/{5V}\right)$$

Removing DC Offset in Differential Amplifiers

DC_OFFSET_DAC (0x1A) – The DC offset between the (+) and (-) terminals of the differential amplifier output can be minimized by writing this DAC. Varying the DAC value from 0 to 4095 can correct up to approximately $\mp 50mV$ of DC offset error. This correction resolution is approximately 0.025 mV per LSB. An approximation of the DAC value to offset voltage is given below.

$$DAC\ Value = 16383\left({V_{Offset} + 0.05V}/{0.1V}\right)$$

Setting the Output Linearity of the IQ Demodulator

LINEARITY_DAC (0x19) – This DAC controls the current draw of the IQ modulator. As rule of thumb, the more current, the better the linearity. However, the user may find that the linearity can be improved with slight adjustments to the current consumption. The linearity is additionally dependent on the operating frequency and input RF power levels. Typically, the DAC is set around 4.5 V using the following equation:

$$DAC\ Value = 16383\left({V_{com}}/{5V}\right)$$

Storing the Startup State

STORE_STARTUP_STATE (0x23) – Writing to this register will save the current device state as the new default power on (startup) state. All data written to this register will be ignored as only the write command is needed to initiate the save.

Writing to the User EEPROM

USER_EEPROM_WRITE (0x1B) - There is an onboard 32 kilobyte EEPROM for the user to store data. User data is sent one byte at a time and is contained in the last (least significant) byte of the three bytes of data written to the register. The other two bytes contain the write address in the EEPROM. For example, to write user data 0x22 into address 0x1F00 requires writing 0x1F0022 to this register.

QUERYING THE SC5312A: WRITING TO REQUEST REGISTERS

The registers to read data back from the device (such as device status) are accessed through the **SC5312A_RegRead** function. The function and parameter format for this command is **SC5312A_RegRead(deviceHandle, registerCommand, instructWord,*dataOut)**. Any instructions in addition to the register call are placed into "instructWord", and data obtained from the device is returned via the pointer value **dataOut**. The set of request registers are shown in Table 3.

Table 3. Query registers.

Register Name	Register Address (Hex)	Serial Range	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
GET_TEMPERATURE	0x20	[7:0]	Open	Open	Open	Open	Open	Open	Open	Open
GET_DEVICE_STATUS	0x21	[7:0]	Open	Open	Open	Open	Open	Open	Open	Open
USER EEPROM_READ	0x23	[7:0]	EEPROM Address [7:0]							
		[15:8]	EEPROM Address [15:8]							
CAL_EEPROM_READ	0x24	[7:0]	EEPROM Address [7:0]							
		[15:8]	EEPROM Address [15:8]							

To read from the device using native USB transfers instead of the **SC5312A_RegRead** function requires two operations. First, a write transfer is made to the device **ENPOINT_OUT** to tell the device what data needs to be read back. Then, a read transfer is made from **ENDPOINT_IN** to obtain the data. The number of valid bytes returned varies from 1 to 3 bytes. See the register details below.

Reading the Device Temperature

GET_TEMPERATURE (0x17) - Data returned by this register needs to be processed to correctly represent data in temperature units of degrees Celsius. Data is returned in the first 14 bits [13:0]. Bit [13] is the polarity bit indicating whether it is positive (0x0) or negative (0x1). For an ENDPOINT_IN transfer, data is returned in 2 bytes with the MSB first. The temperature value represented in the raw data is contained in the next 13 bits [12:0]. To obtain the temperature ADC code, the raw data should be masked (bitwise AND'ed) with 0x1FFF, and the polarity should be masked with 0x2000. The conversion from 12 bit ADC code to an actual temperature reading in degrees Celsius is shown below:

Positive Temperature (bit 13 is 0) = ADC code / 32

Negative Temperature (bit 13 is 1) = (ADC code – 8192) / 32

It is not recommended to read the temperature too frequently, especially once the temperature of the SC5312A has stabilized. The temperature sensor is a serial device located inside the RF module. Therefore, like any other serial device, reading the temperature sensor requires a sending serial clock and data commands from the processor. The process of sending clock pulses on the serial transfer line may cause unwanted spurs on the RF signal as the serial clock could potentially modulate the externally-supplied LO signal within the device.

Reading the Device Status

GET_DEVICE_STATUS (0x21) - This register, summarized in Table 4, returns the device status information such as phase lock status of the PLL, current reference settings, etc. Data is contained in the first three bytes.

Table 4. Description of the status data bits.

Bit	Description
[4]	RF AMP#1 enable
[3]	RF AMP#2 enable
[2]	RF path selection
[1]	LO output enable
[0]	Device accessed

Reading the User EEPROM

USER_EEPROM_READ (0x23) - Once data has been written to the user EEPROM, it can be retrieved by calling this register and using the process outlined in the next section for reading calibration data. The maximum address for this EEPROM is 0x7FFF. A single byte is returned.

Reading the Calibration EEPROM

CAL_EEPROM_READ (0x24) - Reading a single byte from an address in the device EEPROM is performed by writing this register with the address for the instructWord. The data is returned as a byte. The CAL EEPROM maximum address is also 0x7FFF. Reading above this address will cause the device to retrieve data from the lower addresses. For example, addressing 0x8000 will return data stored in address location 0x0000. The calibration EEPROM map is shown in Table 5.

All calibration data, whether floats, unsigned 8-bit, unsigned 16-bit or unsigned 32-bit integers, are stored as flattened unsigned byte representation. A float is flattened to 4 unsigned bytes, so once it is read back it needs to be un-flattened back to its original type. Unsigned values containing more than a single byte are converted (un-flattened) simply by concatenation of the bytes through bit-shifting. Converting to floating point representation is slightly more involved. First, convert the 4 bytes into an unsigned 32-bit integer value, and then (in C/C++) type-cast a float pointer to the address of the value. In C/C++, the code would be float Y = *(float *)&X, where X has been converted earlier to an unsigned integer. An example written in C code would look something like the following:

```
byte_value[4]; // read in earlier
unsigned int uint32_value;
float float32_value;

int count  =  0;
while (count  <  4) {
       uint32_value = unit32_value | (byte_value[count] <<
(count*8));
       count++;
}

float32 value = *(float *)&uint32 value;
```

CALIBRATION EEPROM MAP

Table 5. Calibration EEPROM map.

EEPROM ADDRESS (HEX)	NUMBER OF DATA POINTS	TYPE	DESCRIPTION
0	1	U32	Manufacturing Information
4	1	U32	Product serial number
8	1	U32	RF module number
C	1	U32	Product manufacture date
24	1	F32	Firmware revision
28	1	F32	Hardware revision
2C	40	F32	Reserved
CF	33	U8	Startup state
F4	1	F32	Calibration temperature

SOFTWARE API LIBRARY FUNCTIONS

SignalCore's philosophy is to provide products to our customers whose lower hardware functions are easily accessible. For experienced users who wish to use direct, low-level control of frequency and gain settings, having the ability to access the registers directly is a necessity. However, others may wish for simpler product integration using higher level function libraries and not having to program registers directly. The functions provided in the SC5312A API dynamic linked library or LabVIEW library are:

- **sc5312a_ListResources**
- **sc5312a_OpenDevice**
- **sc5312a_CloseDevice**
- **sc5312a_RegWrite**
- **sc5312a_RegRead**
- **sc5312a_InitDevice**
- **sc5312a_SetFrequency**
- **sc5312a_SetRfGain**
- **sc5312a_SetRfAmplifier**
- **sc5312a_SetRfPath**
- **sc5312a_SetLoOut**
- **sc5312a_SetRfAttenuation**
- **sc5312a_SetRfFilter**
- **sc5312a_SetLoFilter**
- **sc5312a_SetIfGainDac**
- **sc5312a_SetVcomDac**
- **sc5312a_SetDcOffsetDac**
- **sc5312a_SetLinearityDac**
- **sc5312a_WriteUserEeprom**
- **sc5312a_StoreCurrentState**
- **sc5312a_GetDeviceInfo**
- **sc5312a_GetDeviceStatus**
- **sc5312a_GetTemperature**
- **sc5312a_ReadCalEeprom**
- **sc5312a_ReadUserEeprom**

Each of these functions is described in more detail on the following pages. Example code written in C/C++ is located in the *CD:\Win\Driver\src* directory to show how these functions are called and used. First, for C/C++, we define the constants and types which are contained in the C header file, *sc5312a.h*. These constants and types are useful not only as an include for developing user applications using the SC5312A API, but also for writing device drivers independent of those provided by SignalCore.

Constants Definitions

```
// Parameters for storing data in the onboard EEPROM
#define MAXDEVICES                  50    // bytes
#define MAXDESCRIPTORSIZE           25    // bytes
#define CALEEPROMSIZE            32768    // bytes
#define USEREEPROMSIZE           32768    // bytes

// Define labels
#define CH_I                      0x00
#define CH_Q                      0x01
#define RF_ATTEN1                 0x00
#define RF_ATTEN2                 0x01
#define RF_ATTEN3                 0x02
#define RF_AMP1                   0x00
#define RF_AMP2                   0x01

// Define error codes
#define RESERVEDERROR              -1
#define NOTCORRECTDEVICE           -2
#define INPUTNULL                  -3
#define COMMERROR                  -4
#define INPUTNOTALLOC              -5
#define EEPROMOUTBOUNDS            -6
#define INVALIDARGUMENT            -7
#define INPUTOUTRANGE              -8
#define NOREFWHENLOCK              -9
#define NORESOURCEFOUND           -10
#define INVALIDCOMMAND            -11

// Define device registers
#define INITIALIZE                0x01   // initialize the device
#define SET_SYSTEM_ACTIVE         0x02   // set the device “active” LED
#define RF_FREQUENCY              0x10   // set the frequency
#define RF_AMPLIFIER              0x12   // enable amplifiers
#define RF_ATTENUATION            0x13   // set attenuation for digital step attenuators
#define RF_PATH                   0x14   // select the RF path
#define RF_FILTER_SELECT          0x15   // manually select the RF filter
#define LO_FILTER_SELECT          0x16   // manually select the LO filter
#define LO_OUT_ENABLE             0x17   // enable LO output
#define IF_GAIN_DAC               0x18   // set the I and Q chain IF gain
#define VCOM_OUT_DAC              0x19   // sets common output voltage
#define DC_OFFSET_DAC             0x1A   // set the DC offset
#define LINEARITY_DAC             0x1B   // set the linearity DAC (0 to 0xFFF)
#define STORE_STARTUP_STATE       0x1D   // store the current state as default
#define USER_EEPROM_WRITE         0x1F   // write a byte to the user EEPROM
#define GET_DEVICE_STATUS         0x20   // read the device status
#define GET_TEMPERATURE           0x21   // get the internal temperature of the device
#define USER_EEPROM_READ          0x23   // read a byte from the USER EEPROM
#define CAL_EEPROM_READ           0x24   // read a byte from the calibration EEPROM
```

Type Definitions

```
typedef struct
{
	unsigned int productSerialNumber;
	unsigned int rfModuleSerialNumber;
	float firmwareRevision;
	float hardwareRevision;
	unsigned int calDate; // year, month, day, hour:&(0xFF000000,0xFF0000,0xFF00,0xFF)
	unsigned int manDate; // year, month, day, hour:&(0xFF000000,0xFF0000,0xFF00,0xFF)
}	deviceInfo_t;

typedef struct
{
	bool rfAmp1Enable;
	bool rfAmp2Enable;
	bool rfPath;
	bool loEnable;
	bool deviceAccess;
}	deviceStatus_t;
```

Function Definitions and Usage

The functions listed below are found in the *sc5312a.dll* dynamic linked library for the Windows™ operating system. These functions are also provided in the LabVIEW library, *sc5312a.llb*. The LabVIEW functions contain context-sensitive help (Ctrl-H) to assist with understanding the input and output parameters.

Function: **sc5312a_ListResources**

Definition: **int sc5312a_ListResources(char **visaResource, unsigned int *size)**

Output: **char** **visaResource (pointer list to device resources)

Description: **sc5312a_ListResources** searches for SignalCore SC5312A devices connected to the host computer and return an array containing their unique VISA resource ID. This information can be used to open the device(s) using IDs as unique identifiers in the system. See **sc5312a_OpenDevice** function on how to open a device.

Function: **sc5312a_OpenDevice**

Definition: **int sc5312a_OpenDevice(char *visaResource, unsigned int *deviceHandle)**

Input: **char** *visaResource (Resource ID)

Output: **unsigned int** *deviceHandle (unsigned integer number for the deviceHandle)

Description: **sc5312a_OpenDevice** opens the device and turns the front panel “active” LED on if it is successful. It returns a handle to the device for other function calls.

Function: **sc5312a_CloseDevice**

Definition: **int sc5312a_CloseDevice(unsigned int deviceHandle)**

Input: **unsigned int** deviceHandle (handle to the device to be closed)

Description: **sc5312a_CloseDevice** closes the device associated with the device handle and turns off the "active" LED on the front panel if it is successful.

Example: Code to exercise the functions that open and close the device:

```
// Declaring
char **visaResource = (char**)malloc(sizeof(char*)*10); // 10 devices
unsigned int deviceHandle;
int devicesFound;
int i,status;
// Allocate memory for 10 device with 20 characters to hold ID
for(i = 0; i< 10; i++)
       visaResource[i] = (char*)malloc(sizeof(char)*20);

status = sc5312a_ListResources(visaResource, &devicesFound);
 printf("There are %d SignalCore PXI devices found. \n", devicesFound);

if(devicesFound == 0)
//If no device are found deallocate memory and end the program
{
       for(i = 0; i<10;i++)
              free(visaResource[i]);
       free(visaResource);
       printf("No sc5312a devices detected. Press enter to continue.\n");
       return 1;
}

//** sc5505a_OpenDevice, open device 0
status = sc5312a_OpenDevice(visaResource[0], &deviceHandle);

// Free memory
for(i = 0; i<10;i++)
       free(visaResource[i]);
free(visaResource);
 //
// Do something with the device
//
//Close the device
int status = sc5312a_CloseDevice(deviceHandle);
```

Function: **sc5312a_RegWrite**

Definition: **int sc5312a_RegWrite(unsigned int deviceHandle, unsigned char commandByte, unsigned long long int instructWord)**

Input: **unsigned int** deviceHandle (handle to the opened device)
unsigned char commandByte (register address)
unsigned long long int instructWord (data for the register)

Description: **sc5312a_RegWrite** writes the instructWord data to the register specified by the commandByte. See the register map on Table 2 for more information.

Example: To set the frequency to 2 GHz:

```
int status = sc5312a_RegWrite(devHandle, RF_FREQUENCY, 2000000000); // set frequency
```

Function: **sc5312a_RegRead**

Definition: **int sc5312a_RegRead(unsigned int deviceHandle, unsigned char commandByte, unsigned long long int instructWord, unsigned int *receivedWord)**

Input: **unsigned int** deviceHandle (handle to the opened device)
unsigned char commandByte (address byte of the register to write to)
unsigned long long int instructWord (data for the register)
unsigned int *receivedWord (data to be received)

Description: **sc5312a_RegRead** reads the data requested by the instructWord data to the register specified by the commandByte. See Table 3 for details on the registers.

Example: To read the status of the device:

```
unsigned int deviceStatus;

int status = sc5312a_RegRead(devHandle,
GET_DEVICE_STATUS,0x00,&deviceStatus);
```

Function: **sc5312a_InitDevice**

Definition: **int sc5312a_InitDevice(unsigned int deviceHandle, bool mode)**

Input: **unsigned int** deviceHandle (handle to the opened device)
bool mode (set the mode of initialization)

Description: **sc5312a_InitDevice** initializes (resets) the device. Mode = 0 resets the device to the default power up state. Mode = 1 resets the device but leaves it in its current state.

Function: **sc5312a_SetFrequency**

Definition: **int sc5312a_SetFrequency (unsigned int deviceHandle, unsigned long long int frequency)**

Input: **unsigned int** deviceHandle (handle to the opened device)
unsigned long long int frequency (frequency in Hz)

Description: **sc5312a_SetFrequency** sets the RF frequency so the device can automatically use the information to set the optimal filters in the LO and RF filter banks.

Function: **sc5312a_SetRfAmplifier**

Definition: **int sc5312a_SetRfAmplifier(unsigned int devHandle, bool amplifier, bool mode)**

Input: **unsigned int** deviceHandle (handle to the opened device)
bool amplifier (0=AMP#1, 1=AMP#2)
bool mode (disable/enable)

Description: **sc5312a_SetRfAmplifier** enables or disables the RF amplifiers.

Function: **sc5312a_SetRfPath**

Definition: **int sc5312a_SetRfPath(unsigned int deviceHandle, bool mode)**

Input: **unsigned int** deviceHandle (handle to the opened device)
bool mode (0=main path, 1=aux path)

Description: **sc5312a_SetRfPath** selects the RF input port.

Function: **sc5312a_SetLoOut**

Definition: **int sc5312a_SetLoOut(unsigned int deviceHandle, bool mode)**

Input: **unsigned int** deviceHandle (handle to the opened device)
bool mode (0=disable, 1= enable)

Description: **sc5312a_SetLoOut** enables the LO output port. The LO input signal is replicated and made available to the "LO out" port.

Function: **sc5312a_SetRfAttenuation**

Definition: **int sc5312a_SetRfAttenuation(unsigned int deviceHandle, unsigned char attenuator, unsigned char atten)**

Input: **unsigned int** deviceHandle (handle to the opened device)
unsigned char attenuator (selects the attenuator to program)
unsigned char atten (attenuation value (0-31 dB))

Description: **sc5312a_SetRfAttenuation** sets the attenuation level of the RF attenuators.

Function: **sc5312a_SetRfFilter**

Definition: **int sc5312a_SetRfFilter(unsigned int deviceHandle, unsigned char filter)**

Input: **unsigned int** deviceHandle (handle to the opened device)
unsigned char filter (select the appropriate filter number 0-8)

Description: **sc5312a_SetRfFilter** selects the active filter in the RF filter bank.

Function: **sc5312a_SetLoFilter**

Definition: **int sc5312a_SetLoFilter(unsigned int deviceHandle, unsigned char filter)**

Input: **unsigned int** deviceHandle (handle to the opened device)
unsigned char filter (select the appropriate filter number 0-8)

Description: **sc5312a_SetLoFilter** selects the active filter in the LO filter bank.

Function: **sc5312a_SetIfGainDac**

Definition: **int sc5312a_SetIfGainDac(unsigned int deviceHandle, unsigned char channel, unsigned char dacValue)**

Input:
unsigned int deviceHandle (handle to the opened device)
unsigned char channel (select the I or Q channel)
unsigned char dacValue (DAC value range 0 - 63)

Description: **sc5312a_SetIfGainDac** sets the gain of the IF amplifier.

Function: **sc5312a_SetVcomDac**

Definition: **int sc5312a_SetVcomDac(unsigned int deviceHandle, unsigned char channel, unsigned short dacValue)**

Input:
unsigned int deviceHandle (handle to the opened device)
unsigned char channel (select the I or Q channel)
unsigned short dacValue (DAC value range 0 - 4095)

Description: **sc5312a_SetIfGainDac** sets the common output voltage of the differential amplifiers. The default factory setting is 2008.

Function: **sc5312a_SetDcOffsetDac**

Definition: **int sc5312a_SetDcOffsetDac(unsigned int deviceHandle, unsigned char channel, unsigned short dacValue)**

Input:
unsigned int deviceHandle (handle to the opened device)
unsigned char channel (select the I or Q channel)
unsigned short dacValue (DAC value range 0 - 4095)

Description: **sc5312a_SetDcOffsetDac** sets the DC offset voltage of the differential amplifiers. Voltage adjust is approximately +/- 0.05 V. The default factory setting is 2048.

Function: **sc5312a_SetLinearityDac**

Definition: **int sc5312a_SetLinearityDac(unsigned int deviceHandle, unsigned short dacValue)**

Input:
unsigned int deviceHandle (handle to the opened device)
unsigned short dacValue (DAC value range 0 - 4095)

Description: **sc5312a_SetLinearityDac** sets the current consumption of the IQ demodulator, which affects the linearity of the device. A DAC value of 3685 is recommended and is also the default factory setting.

Function: **sc5312a_WriteUserEeprom**

Definition: **int sc5312a_WriteUserEeprom(unsigned int deviceHandle, unsigned int memAdd, unsigned char byteData)**

Input: **unsigned int** deviceHandle (handle to the opened device)
unsigned int memAdd (memory address to write to)
unsigned char byteData (byte to be written to the address)

Description: **sc5312a_WriteUserEeprom** writes one byte of data to the memory address specified.

Function: **sc5312a_StoreCurrentState**

Definition: **int sc5312a_StoreCurrentState(unsigned int deviceHandle)**

Input: **unsigned int** deviceHandle (handle to the opened device)

Description: **sc5312a_StoreCurrentState** stores the current state of the device as the default power-up state.

Function: **sc5312a_GetDeviceInfo**

Definition: **int sc5312a_GetDeviceInfo(unsigned int deviceHandle, deviceInfo_t *devInfo)**

Input: **unsigned int** deviceHandle (handle to the opened device)

Output: **deviceInfo_t** *devInfo (device info struct)

Description: **sc5312a_GetDeviceInfo** retrieves device information such as serial number, calibration date, revision, etc.

Function: **sc5312a_GetDeviceStatus**

Definition: **int sc5312a_GetDeviceStatus(unsigned int deviceHandle, deviceStatus_t *deviceStatus)**

Input: **unsigned int** deviceHandle (handle to the opened device)

Output: **deviceStatus_t** *deviceStatus (deviceStatus struct)

Description: **sc5312a_GetDeviceStatus** retrieves the status of the device such as phase lock status and current device settings.

Example: Code showing how to use this function:

```
deviceStatus_t *devStatus;
devStatus = (deviceStatus_t*)malloc(sizeof(deviceStatus_t));

int status = SC5312A_GetDeviceStatus(devHandle, devStatus);

if(devStatus->loEnable)
printf("The LO Output Port is Enabled \n");
else
printf("The LO Output Port is disabled \n");

free(deviceStatus);
```

Function: **sc5312a_GetTemperature**

Definition: **int sc5312a_GetTemperature(unsigned int deviceHandle, float *temperature)**

Input: **unsigned int** deviceHandle (handle to the opened device)

Output: **float** *temperature (temperature in degrees Celsius)

Description: **sc5312a_GetTemperature** retrieves the internal temperature of the device.

Function: **sc5312a_ReadCalEeprom**

Definition: **int sc5312a_ReadCalEeprom(unsigned int deviceHandle, unsigned int memAdd, unsigned char *byteData)**

Input: **unsigned int** deviceHandle (handle to the opened device)

unsigned int memAdd (EEPROM memory address)

Output: **unsigned char** *byteData (the read back byte data)

Description: **sc5312a_ReadUserEeprom** reads back a byte from a specific memory address of the calibration EEPROM.

Function: **sc5312a_ReadUserEeprom**

Definition: **int sc5312a_ReadUserEeprom(unsigned int deviceHandle, unsigned int memAdd, unsigned char *byteData)**

Input: **unsigned int** deviceHandle (handle to the opened device)

unsigned int memAdd (EEPROM memory address)

Output: **unsigned char** *byteData (the read back byte data)

Description: **sc5312a_ReadUserEeprom** reads back a byte from a specific memory address of the user EEPROM.

CALIBRATION & MAINTENANCE

The SC5312A does not receive a factory calibration. The SC5312A is sold as a component and users will need to perform amplitude and IQ correction as part of their system, which may minimally include a digitizer, LO source, and the SC5512A. Should users require SignalCore to perform any calibration, please contact SignalCore support directly.

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